

## XYSTRIDURA AND OTHER EARLY MIDDLE CAMBRIAN TRILOBITES FROM YAXIAN, HAINAN PROVINCE, CHINA

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### Summary

LIN, TIAN-RUI & JAGO, J. B. (1993) *Xystridura* and other early Middle Cambrian trilobites from Yaxian, Hainan Province, China. *Trans. R. Soc. S. Aust.* 117(3), 141-152, 30 November, 1993.

Xystridurine trilobites are an important element of early Middle Cambrian faunas of Australia, China and Antarctica. An early Middle Cambrian trilobite fauna is described from the Damao phosphate mine of the Yaxian district, Hainan Province, People's Republic of China. These include *Pagella luoyacunensis* sp. nov., *Xystridura hainanensis* Sun, 1963, *X. yaxianensis* Zhu & Lin, 1978, *X. orientalis* Zhu & Lin, 1978, *Galahetes hainanensis* Zhu & Lin, 1978 and *Kootenia* sp. The species of *Xystridura* are described in considerably more detail than previously possible due to the discovery of new material particularly pygidia. It is suggested that the three subgenera of *Xystridura* erected by Öpik (1975) are of doubtful value. *Galahetes pyrus* Zhu & Lin, 1978 is placed in synonymy with *G. hainanensis*.

KEY WORDS: Middle Cambrian trilobites, China, Australia, *Xystridura*, *Galahetes*.

### Introduction

*Xystridura* is an important early Middle Cambrian trilobite genus which is known from the Northern Territory (Öpik 1975), Queensland (Whitehouse 1939; Öpik 1975), South Australia (Gatehouse 1986), and western New South Wales (Wopfner 1966; Öpik 1968, 1975). *Xystridura templetonensis* is one of the nominate species of the *Xystridura templetonensis/Redlichia chinensis* Zone of the early Middle Cambrian of northern Australia. *Xystridura* was known only from Australia prior to its discovery on Hainan Island, China (Sun 1963). It is now known from elsewhere in China (e.g. Zhou *et al.* 1982) as well as Antarctica (e.g. Palmer & Gatehouse 1972). Öpik (1975) described a second member of the Xystridurinae, *Galahetes*, from the early Middle Cambrian of Queensland; it has since been recorded from Hainan (Zhu & Lin 1978) and Gansui, northeast China (Zhou *et al.* 1982). McNamara (1981) discussed the evolution of the Middle Cambrian xystridurine trilobites from northern Australia.

The purpose of this paper is to revise the work of Sun (1963) and Zhu & Lin (1978) and to describe the trilobites (including species of both *Xystridura* and *Galahetes*) from the *Xystridura* Zone of the early Middle Cambrian Damao Formation from the Damao phosphate mine of the Yaxian district, Hainan Province, People's Republic of China (Fig. 1). The area contains some of the most important phosphate deposits in China. As listed below the Damao Formation is richly

fossiliferous and includes trilobites, bradoriids, brachiopods, bivalves, hyoliths, microfossils, etc. Data on the trilobites have been previously published by Sun (1963) and Zhu & Lin (1978). The present material, which was collected by Lin Tian-Rui in 1987, 1988 and 1991 provides extra specimens which give a better understanding to the previously described species. In particular, it has allowed the pygidia of the various species of *Xystridura* to be identified, which is important because the pygidium provides one of the key features in separating the different species of *Xystridura*. In addition this paper provides stratigraphic information on the distribution of trilobites which was not given in the papers of Sun (1963) and Zhu & Lin (1978).

The stratigraphic section at Damao as described by Zhang Xiguang (1986), and revised in this paper, is given in descending order as follows.

Damao Formation (top and bottom not exposed)

12. Grey thin to medium-bedded siliceous rock intercalated with silty and muddy shale, containing brachiopod fragments. 12.1m
11. Grey and yellowish grey thin to medium-bedded micaceous siltstone intercalated with a few siliceous shale beds, yielding bradoriids: *Houlongdongella disulcata* Loc., *H. sphaerica* Zhang, *Ophiosema strumatum* Zhang, *O. sicyadeum* Zhang, *Ophiosema (Sinophiosema) chinense* Zhang, *O. (S.) transversum* Zhang, *O. (S.) delatum* Zhang, *O. (S.) paradoxum* Zhang, *Guangdongella obesa* Zhang and the brachiopod *Lingulella liui* Sun. 1.2m
10. Dark grey medium-bedded siliceous siltstone, bearing the trilobite *Xystridura* sp. 6.1m
9. Greyish white and greyish yellow thin to medium-bedded siliceous siltstone intercalated with silty and

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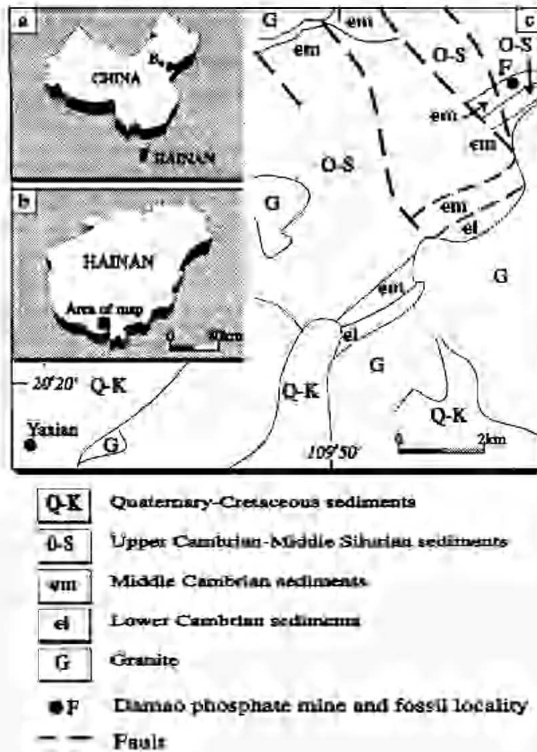


Fig. 1. Locality map. In box A, B indicates Beijing.

muddy shales, containing the bradoriids *Ophiosema subrotundum* Zhang and *Mannocosmia* sp.; the trilobites *Xystridura hainanensis* Sun, *X. yaxianensis* Zhu & Lin, *X. orientalis* Zhu & Lin and *Galahetes hainanensis* Zhu & Lin; brachiopods *Lingulella tangshihensis* Resser & Endo and *Acrothele* sp. 2.5m

8. Greyish yellow siliceous shale intercalated with thin to medium-bedded siliceous siltstone and containing trilobites *Xystridura orientalis* Zhu & Lin and *Pagetia luoyacunensis* sp. nov. 5.3m
7. Greyish white and grey medium-bedded siltstone and siliceous shale, containing the bradoriids: *Houlongdongella disulcata* Lee, *H. inflata* Zhang, *Yaxianella sulcata* Lin, *Y. punctata* Zhang, *Ophiosema strumatum* Zhang, *O. subrotundum* Zhang, *Indota acuta* Zhang, *Guangdongella obesa* Zhang, *Mannocosmia torquata* Zhang, *Plesidelymella* sp., *Bradoria* sp.; trilobites *Xystridura hainanensis* Sun, *X. orientalis* Zhu & Lin, *Galahetes hainanensis* Zhu & Lin, *Kootenia* sp. and *Pagetia luoyacunensis* sp. nov.; brachiopods *Lingulella tangshihensis* Resser & Endo, and *Homotreia* sp. 5.2m

6. Dark grey siliceous shale and phosphatic siliceous rock intercalated with dark grey phosphorite, containing the bradoriid *Indota acuta* Zhang; the trilobites *Xystridura hainanensis* Sun, *X. orientalis* Zhu & Lin, and *Pagetia luoyacunensis* sp. nov. 9.6m
5. Dark brown nodular manganese ore bed (thickness about 2m), with siliceous shale at the base, yielding brachiopod fragments. 2.6m
4. Greyish white and dark grey medium to thick-bedded siliceous siltstone and quartzose sandstone intercalated with dolomite and a few micaceous muddy shales. 42.2m
3. Greyish green and greenish red medium and thin-bedded micaceous siltstone intercalations. 55.8m
2. Greyish white massive quartzose sandstone and siliceous siltstone intercalated with a few medium to thick-bedded dolomite horizons. 8.3m
1. Greyish white massive medium-grained quartzose sandstone. 35.8m

#### Age and affinities of fauna

The trilobites described herein comprise the following species *Pagetia luoyacunensis* sp. nov., *Xystridura hainanensis* Sun, *X. yaxianensis* Zhu & Lin, *X. orientalis* Zhu & Lin, *Galahetes hainanensis* Zhu & Lin, and *Kootenia* sp. In China *Xystridura* and *Galahetes* are known from the Tianshan (Wang *et al.* 1985) and from Gansu (Zhou *et al.* 1982). The age here is equivalent to the Maozhuangian Stage of the North China biostratigraphic scheme. In Australia *Xystridura* and *Galahetes* are important members of the early Middle Cambrian fauna of Australia (Öpik 1975). The various species of *Xystridura* described by Öpik (1975) are either of Ordian or Templetonian age. In Australia *Xystridura* is known from the Northern Territory (Öpik 1975), Queensland (Whitehouse 1939; Öpik 1975), western New South Wales (Wopfner 1966; Öpik 1968, 1975) and from the Kalladeina Formation of the Warburton Basin in northeastern South Australia (Gatehouse 1986). In Australia *Galahetes* has been recorded from the Templetonian of the Duchess area (Öpik 1975). *Xystridura* has also been described from early Middle Cambrian rocks of Antarctica (Palmer & Gatehouse 1972; Soloviev & Grikurov 1979). In summary members of the Xystriduridae are an important element of the very early Middle Cambrian faunas of Australia, Antarctica and China.

The specimens described herein show some tectonic distortion. They are deposited at either the Nanjing Institute of Geology and Palaeontology, Academia Sinica (NIGP) or the Department of Earth Sciences, Nanjing University (NUESD). All figured specimens were whitened with magnesium oxide prior to photography.

**Systematic descriptions**

Suborder EODISCINA Kobayashi, 1939

Family PAGETIIDAE Kobayashi, 1935

Genus PAGETIA Walcott, 1916

*Synonymy*: See Jell 1975, p. 30.*Type Species*: *Pagetia bootes* Walcott, 1916, p. 408, Pl. 67, Figs 1, la-f.*Diagnosis*: See Jell 1975, p. 30.***Pagetia luoyacuensis* sp. nov.**

FIGS 2a-f, 6d.

*Dawsonia dawsoni*: Sun 1963 p. 610, Pl. 1, Figs 7, 7a.*Pagetia* sp. Zhu & Lin 1978 p. 439, Pl. 1, Fig. 1.*Material*: 11 cranidia and nine pygidia.*Etymology*: After the nearby town of Luoyacun.*Holotype*: The cranidium (NUESD 210), Fig. 2b, is chosen as the holotype.*Diagnosis*: Member of *Pagetia* with anteriorly tapered glabella; cranidial spine has length about two-thirds that of glabella; shallow transglabellar furrow close to glabella anterior; wide fixed cheeks; palpebral lobes extend from opposite transglabellar furrow to opposite anterior of spine; well-developed palpebral furrows; short (sag.), strongly depressed preglabellar field; wide border; 16-20 cephalic border serobicules stop just short of margin. Pygidium with gently tapering axis which stops just short of posterior margin. Axis comprises four axial rings and terminus. Each axial ring and terminus bears spine base. Pleural areas with three pairs of pleural furrows; narrow border. Fairly pustulose surface ornament.*Description*: Cranidium with anteriorly tapered glabella, length about 0.6-0.65 that of cranidium; shallow transglabellar furrow placed close to well-rounded glabella anterior. Well-developed cranidial spine, length about two thirds that of glabella. Axial furrows deep, wide; baculae absent. Wide fixed cheeks, palpebral lobes extend from opposite transglabellar furrow to opposite anterior of spine; well-developed palpebral furrows; narrow but distinct eye ridges meet axial furrows just forwards of transglabellar furrow. Short, strongly-depressed preglabellar field; wide anterior border furrow not crossing lateral border. Wide border with 16-20 radial serobicules which stop just short of margin. Wide, deep posterior border furrow.

Semicircular pygidium. Axis tapers gradually rearwards; it extends almost to posterior margin. Axis comprises four axial rings and terminus. On available specimens each axial ring bears spine base as does terminus. Semi-elliptical articulating half-ring. Pleural areas contain three pairs of pleural furrows. Narrow shallow border furrow; narrow border. Both cranidium and pygidium have finely pustulose surface ornament.

*Discussion*: Prior to the specimens described herein, this species was known from only the two very poorly preserved cranidia figured in Sun (1963, Pl. 1, Figs 7, 7a) and Zhu & Lin (1978, Pl. 1, Fig. 1). Although somewhat distorted the available material indicates that it should be the basis of a new species. Of the Australian species of *Pagetia* described by Jell (1975), the new species *P. luoyacuensis* is probably closest to *P. howardi* Jell. The cranidia of the two species are quite similar, although the cephalic border of *luoyacuensis* is wider than that of *howardi*. The pygidial axis of *luoyacuensis* is wider than that of *howardi*.*P. luoyacuensis* differs from the type species of *Pagetia*, *P. bootes* Walcott (e.g. see Rasetti 1966, p. 504, Pl. 59, Figs 11-13), in that *P. bootes* has a wider and shallower preglabellar field, a longer and more slender cranidial spine, a narrower pygidial axis with five axial rings plus a terminus bearing a long spine and a smoother pleural field. There are some similarities between *P. luoyacuensis* and *P. quebecensis* Rasetti (1966, p. 506, Pl. 59, Figs 5-10) but *P. luoyacuensis* differs from *P. quebecensis* in having small palpebral lobes, in having distinct baculae and in not having pronounced spine bases on the pygidial axis.**Order REDLICHIDA Richter, 1933**

Suborder REDLICHINA Harrington, 1959

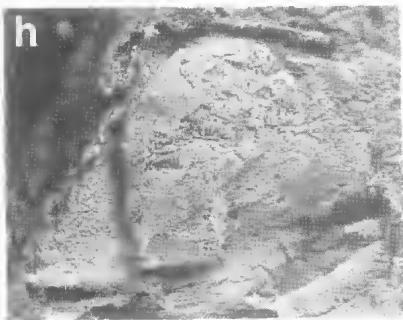
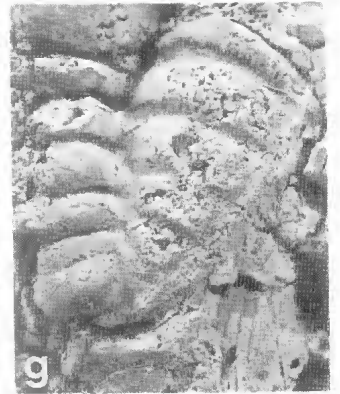
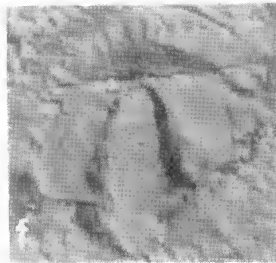
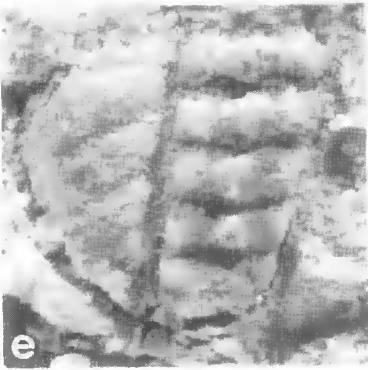
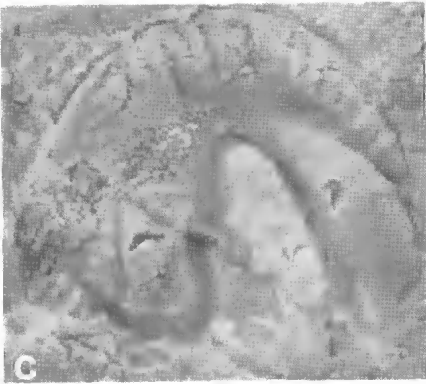
Superfamily PARADOXIDACEA Hawle &amp; Corda, 1847

Family CENTROPLEURIDAE Angelin, 1854

Genus XYSTRIDURA Whitehouse, 1936

*Type Species*: *Xystridura templetonensis* (Chapman) — *Milesia templetonensis* Chapman, 1929, p. 214, Pl. 22, Fig. 19, refigured by Whitehouse 1939, Pl. 21, Fig. 10 (see also comments by Palmer & Galehouse 1972, p. 13).*Diagnosis*: See Öpik 1975, p. 20, 31.*Discussion*: Öpik (1975) discussed *Xystridura* in some detail. He suggested that there should be at least three subgenera in *Xystridura*, i.e. *X. (Xystridura)*, *X. (Polydinotes)* and *X. (Inosacotes)* with the type of *X. (Xystridura)* being *X. templetonensis*. In his differential diagnosis Öpik (1975, p. 31) states "In *Inosacotes* and *Polydinotes* the cephalic test is strongly ornamented, the thorax expands rearwards, the pygidial axial lobe is fused with the thorax, and the pygidial margin is visibly denticulate; furthermore in *Polydinotes* the pleural tips are hispinose (simple in *Xystridura* and *Inosacotes*) and in *Inosacotes* the anterior facial sutures are fused (functional in *Xystridura* and *Polydinotes*)".It should be noted that species included by Öpik in *X. (Xystridura)* also show a thorax which expands rearwards, e.g. *X. milesi* (see Öpik 1975, Pl. 14, Fig. 2), and *X. carteri* (see Öpik 1975, Pl. 15, Fig. 1). The





present authors do not regard the caecal patterns shown in the species of *Iusacotes* and *Polydinotes* as being of subgeneric taxonomic significance. This plus the variations allowed for by Öpik would suggest that his subgeneric groupings may be of doubtful value.

*Xystridura hainanensis* Sun, 1963

FIG. 3a-h

*Xystridura hainanensis* Sun, 1963 p. 608, Pl. 1, Figs 1-4; Zhu & Lin: 1978 p. 440, Pl. 1, Figs 2, 3 (non 4a, 4b).

*Material*: Twenty cranidia and eight pygidia.

*Lectotype* (designated herein). The pygidium figured by Sun (1963, Pl. 1, Figs 4, 4a) is selected as lectotype. Sun did not erect a holotype.

*Diagnosis*: Species of *Xystridura* in which glabella extends almost to anterior border furrow; glabella anterior broadly rounded. Long palpebral lobes extend from opposite anterior of occipital ring to just forwards of 3p furrows. Anterior end of palpebral lobe almost meets axial furrow. Pygidium with short axis; with four axial rings and a terminus. Two pairs of marginal spines; very long, slender anterior pair directed posterolaterally at an angle of about 45°; second pair short.

*Description*: Cranidium wide (tr.), slightly convex, with a length about two-thirds the width between palpebral lobes. Glabella extends almost to anterior border furrow; preglabellar field very short (sag.) but clearly separates preglabellar furrow from anterior border furrow; glabellar length about 0.85 that of cranidium. Glabella has slight waist at 1p furrows; widest just forwards of 3p furrows; broadly rounded glabellar anterior. Narrow axial furrow of moderate depth. Three pairs of lateral glabellar furrows. Each 1p furrow is directed slightly to posterior and extends about 0.4 of distance across glabella; 2p furrows almost horizontal; 3p furrows slightly arcuate with convexity to anterior. 3p furrows, slightly convex anteriorly, set in from axial furrow and not connecting with it. Narrow occipital furrow deepest abaxially. Occipital ring widest centrally; small median node. Long palpebral lobes extend from opposite anterior of occipital ring to just forwards of 3p furrows. Palpebral furrow very shallow, barely discernible on many specimens. Palpebral areas of fixigenae wide and flat; at posterior end width 0.5-0.6 that of glabella; anterior end narrow where anterior of palpebral lobe almost meets axial furrow. Anterior areas of fixigenae almost

flat. Preocular sections of facial suture diverge markedly. Very short postocular sections of facial suture diverge slightly. Wide anterior border with shallow terrace lines; narrow anterior border furrow. Shallow posterior border furrow. Very narrow posterolateral border.

Pygidium very wide (tr.) with length about half width. Short axis extends just over half length of pygidium. Axis has four axial rings plus terminus. Wide pleural field with at least two pairs of pleural furrows and two pairs of interpleural furrows. Two pairs of marginal spines. Anterior pair arise from first pleurae of pygidium; very long slender spines with wide base; directed posterolaterally at angle of about 45°. Second pair short, pointed with wide base. It is possible that there is a very short third pair of spines but this is difficult to determine on available material.

*Discussion*: The pygidia shown by Zhu & Lin (1978, Pl. 1, Figs 4a, b) as belonging in *X. hainanensis* are now placed in *X. orientalis*. When compared with the Australian species described by Öpik (1975) *X. hainanensis* is probably closest to *X. fracta* in that the cranidia are quite similar. The pygidia are similar in terms of lengths of pygidial axis but differ in the presence of the longer spines in *X. hainanensis* and in the nature of the pygidial pleural and interpleural furrows.

The anterior pygidial spines of *hainanensis* are longer than in any other species of *Xystridura* with the possible exception of *X. glacia* Palmer & Gatehouse, 1972. However, *glacia* has three relatively narrow pygidial spines whereas *hainanensis* has two spines, each with a large base. The anterior pygidial spine of *X. glacia* at its distal end is directed approximately parallel to the axis; this is not so in *X. hainanensis*, even allowing for tectonic distortion.

*Xystridura yaxianensis* Zhu & Lin, 1978

FIG. 4a-e.

*Xystridura yaxianensis* Zhu & Lin, 1978 p. 440, Pl. 1, Figs 5-6.

*Xystridura orientalis* Zhu & Lin, 1978 p. 441, Pl. 1, Fig. 8 only.

*Material*: One specimen comprising the cranidium, the right librigena, most of the thorax and the pygidium; 14 cranidia and four pygidia. None is well preserved. *Holotype*: The cranidium (NIGP 44903) figured by Zhu & Lin (1978, Pl. 1, Fig. 5) and refigured here as Fig. 4d.

Fig. 2. a-c, *Pagetia luoyacuenensis* sp. nov. a, NUESD 207, cranidium x20; b, NUESD 210, holotype cranidium, x20; c, NUESD 212, cranidium, x20; d, pygidium, x20; e, NUESD 214, pygidium, x20; f, cranidium (figured as *Pagetia* sp. by Zhu & Lin 1978, Pl. 1, Fig. 1), x20.  
g-i, *Kootenia* sp. g, NUESD 218, partial pygidium, x5; h, NIGP 44916, partial cranidium (figured by Zhu & Lin 1978, Pl. 2, Fig. 8); i, pygidium, NUESD 219, x8.  
All specimens are internal moulds.

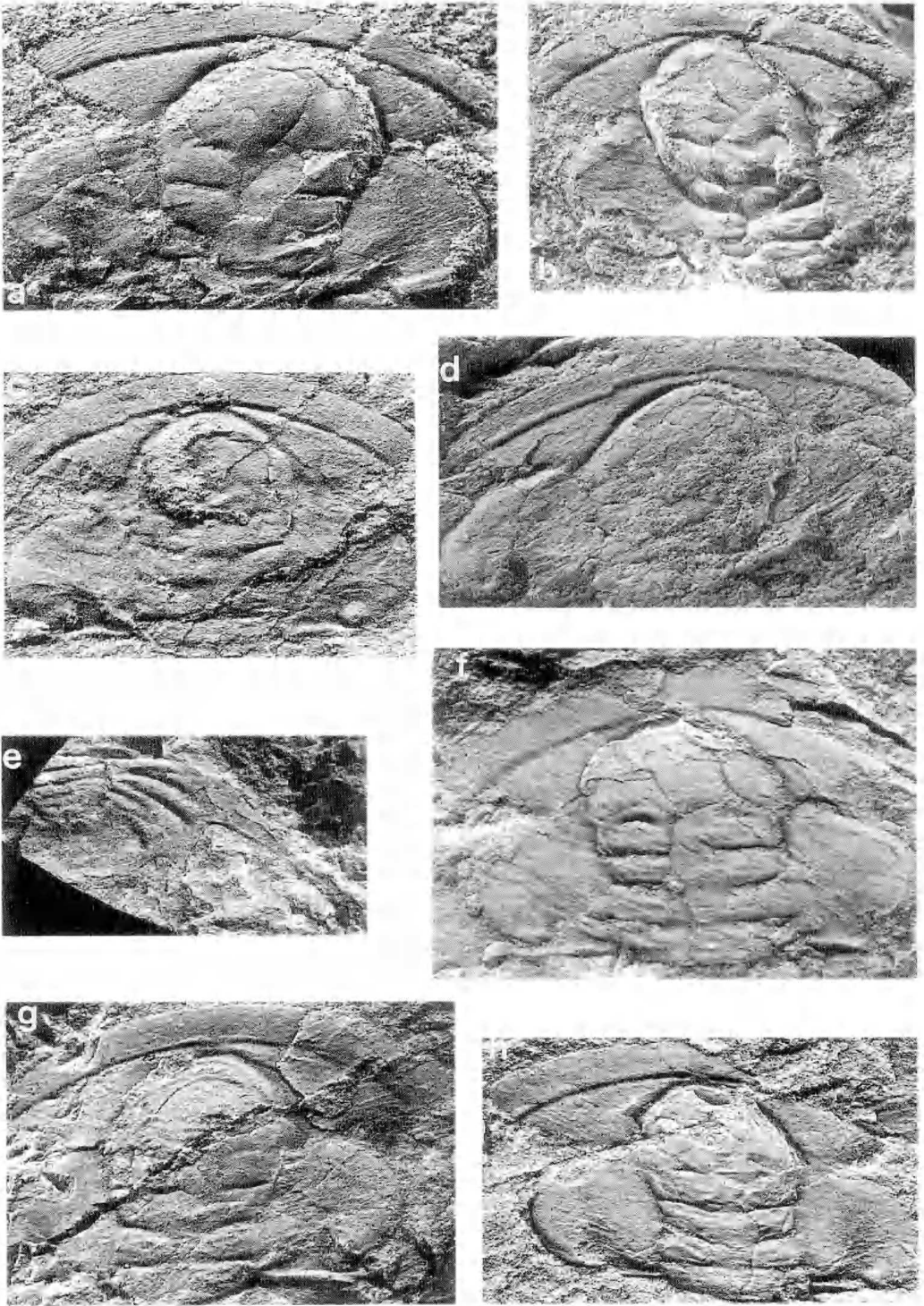


Fig. 3. *Xystridura hainanensis* Sun, 1963. a, NUESD 220, cranidium, x4; b, NUESD 217, cranidium, x4; c, NUESD 222, cranidium, x4; d, NUESD 225, cranidium, x4; e, NUESD 228, pygidium, x2.5; f, NUESD 221, cranidium, x2; g, NUESD 223, cranidium, x3.5; h, NUESD 224, cranidium, x3. All specimens are internal moulds.



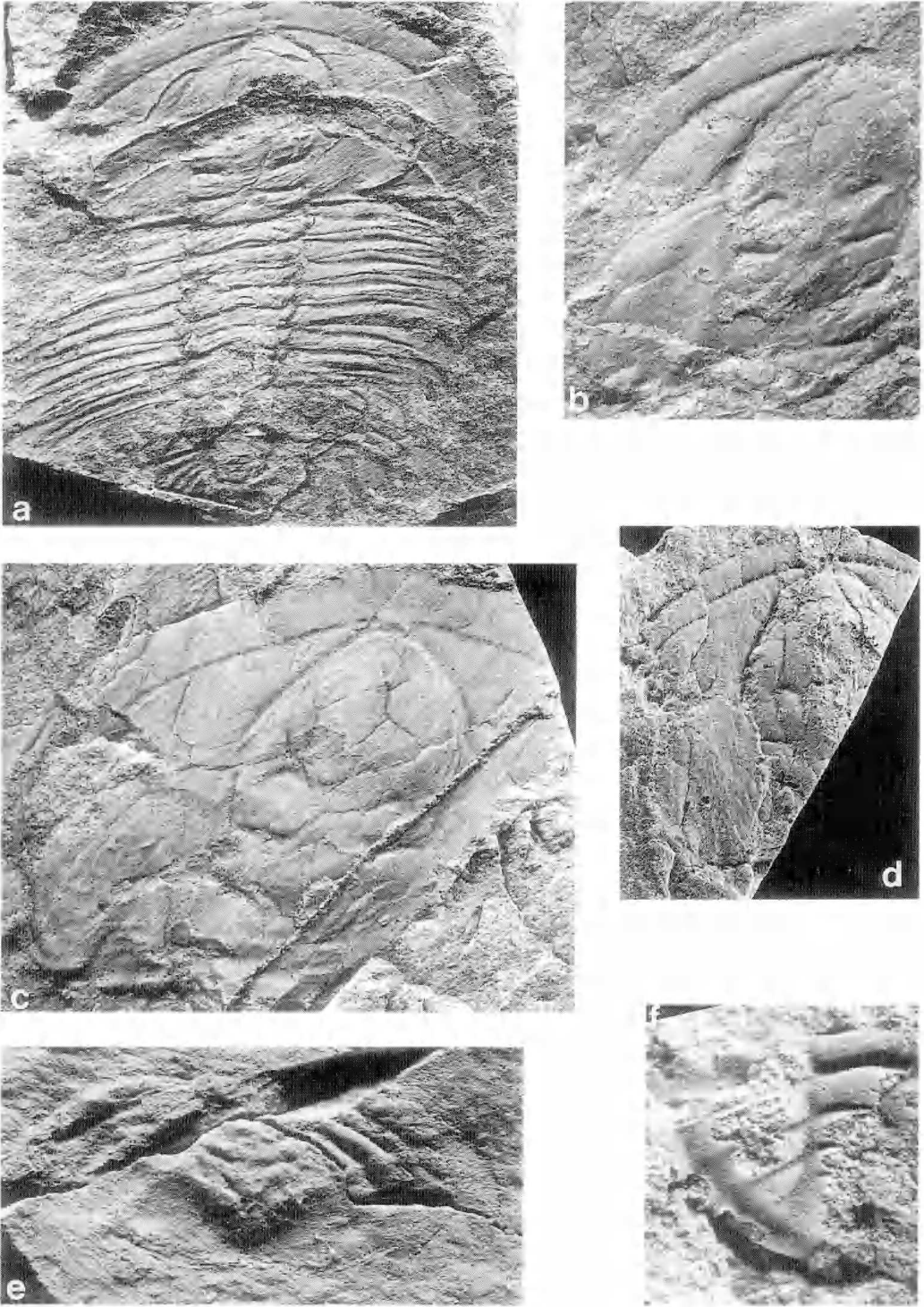
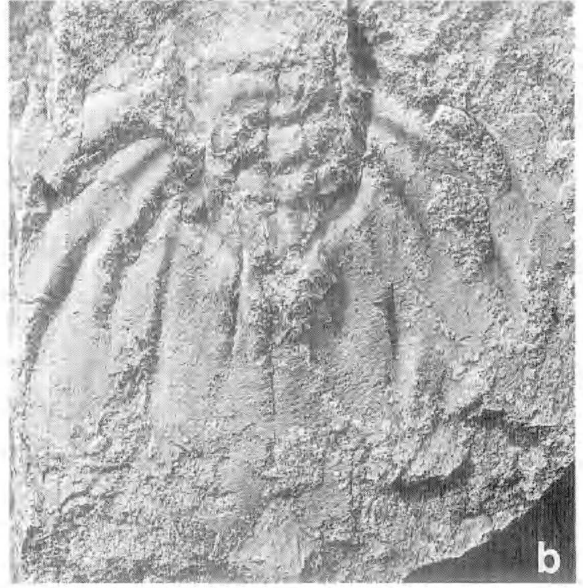


Fig. 4. a-e *Xystridura yaxianensis* Zhu & Lin, 1978. a, NUESD 229, almost complete specimen, rubber cast of external mould, x2; b, cranium, rubber cast of external mould, x3; c, NUESD 234, cranium, rubber cast of external mould, x3; d, NIGP, holotype cranium (originally figured by Zhu & Lin 1978, Pl. 1, Fig. 5), internal mould, x2; e, NIGP 44906, pygidium, (originally figured by Zhu & Lin 1978, Pl. 1, Fig. 8 as belonging to *X. orientalis*), internal mould, x4; f, *Kootenia* sp., NIGP 44917, pygidium, (originally figured by Zhu & Lin 1978, Pl. 2, Fig. 9), internal mould, x5.





**Diagnosis:** Species of *Xystridura* in which glabella extends almost to anterior border. Sharply rounded glabellar anterior. Short pygidial axis. Three pairs of pygidial spines. Moderately long, anterior pair with wide base directed outwards and backwards; second shorter pair extend inwards and backwards; third pair very short. Central posterior margin of pygidium broadly curved to anterior.

**Description:** Cephalon semi-circular. Glabella extends almost to anterior border furrow; length about 0.85-0.9 that of cranidium. Glabella with slight waist at about 2p furrows; widest just anterior to 3p furrows. Glabellar anterior sharply rounded. Narrow axial furrow of moderate depth. Three pairs of lateral glabellar furrows. Each 1p furrow directed slightly to posterior; they almost meet abaxially; 2p furrows almost horizontal; 3p furrows which do not meet the axial furrow slightly arcuate with convexity to anterior. Both palpebral and anterior sections of fixigenae almost flat. Narrow occipital furrow. Occipital ring widest abaxially; faint occipital node. Long palpebral lobes extend from opposite occipital ring just anteriorly of 3p furrows. Shallow palpebral furrow. Preocular sections of facial suture diverge markedly. Narrow shallow anterior border furrow; wide anterior border with faint terrace lines on some specimens. Shallow posterior border furrow; very narrow posterolateral border. Poorly preserved librigena with narrow shallow border furrow; wide border extends into genal spine of indeterminate length. Thorax of 12 segments. Shallow axial furrows. Width of axis about 0.6 that of pleural regions. Axis parallel sided from first to fifth segment gradually narrowing posteriorly. Pleurae almost flat; pleural furrows narrow abaxially but continue as shallow furrow into well-developed posteriorly directed pleural spines.

Available pygidia poorly preserved. Axis comprises four axial rings plus terminus. Wide pleural field with at least two pairs of pleural furrows and two pairs of interpleural furrows. Wide flat border with faintly-developed terrace lines. Three pairs of marginal spines. Anterior pair extending from first pleural segment of pygidium; of moderate length with wide base and extending posterolaterally. Second shorter pair extending posteromedially. Third pair very short; more change of slope in pygidial margin than distinct spines. Central posterior margin broadly curved to anterior. **Discussion:** When compared with the species described by Opik, *X. yaxianensis* is closest to *X. templetonensis*.

However the cranidium of *yaxianensis* has a more sharply rounded glabellar anterior and longer palpebral lobes than *templetonensis*. *X. yaxianensis* differs from *X. hainanensis* in having a more sharply rounded glabellar anterior and a longer pygidial axis. The pygidial spines in the two species are quite different.

The pygidium (NIGP 44906) figured here (Fig. 4e) as *X. yaxianensis* was originally assigned by Zhu & Lin (1978, Pl. 1, Fig. 8) to *X. orientalis*. However, the discovery of the partially complete specimen figured as Fig. 4a indicates that NIGP 44906 should be reassigned.

*Xystridura orientalis* Zhu & Lin, 1978  
FIG. 5a-g; FIG. 6a,b,h.

*Xystridura orientalis* Zhu & Lin, 1978 p. 441, Pl. 1, Fig. 7; Pl. 2, Figs 1-3.

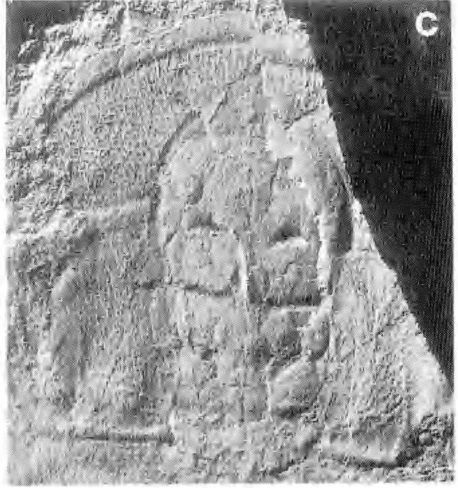
**Material:** One incomplete cranidium with three incomplete thoracic segments, 15 incomplete cranidia, four free cheeks and 12 incomplete pygidia.

**Holotype:** The cranidium (NIGP 44905) figured by Zhu & Lin 1978 (Pl. 1, Fig. 7) and refigured here as Fig. 5g.

**Diagnosis:** Species of *Xystridura* in which glabella extends almost to anterior border. Sharply rounded glabellar anterior. Short pygidial axis comprising three axial rings plus terminus. Three pairs of pygidial spines; anterior pair long, wide and directed slightly laterally to slightly medially; second pair long, wide and directed very slightly medially; third pair very short; posterior pygidial margin minutely denticulate.

**Description:** Glabella extends almost to anterior border furrow; length about 0.9 that of cranidium. Glabella has slight waist at 1p furrows; widest just anteriorly to 3p furrows. Glabellar anterior sharply rounded. Narrow shallow axial furrow. Three pairs of lateral glabellar furrows; 1p furrows directed posteromedially; 2p furrows directed slightly posteriorly; 3p furrows essentially elongated slightly anteriorly curved pits. Shallow occipital furrow deepest abaxially. Occipital ring bears small low median node. Palpebral lobe extends from opposite anterior end of occipital ring to just anteriorly of 3p furrows. Very shallow palpebral furrows. Palpebral areas of fixigenae wide, flat; narrow at anterior. Preocular sections of facial suture diverge markedly. Postocular sections of facial suture nowhere well preserved. Wide anterior border with faint terrace

Fig. 5. *Xystridura orientalis* Zhu & Lin, 1978. a, NUESD 235, cranidium plus three anterior thoracic segments, internal mould, x2; b, NUESD 238, pygidium, internal mould, x4; c, NUESD 236, librigena and partial cranidium, rubber cast of external mould, x2; d, NUESD 245, pygidium, rubber cast of external mould, x2; e, NUESD, cranidium, internal mould, x4; f, NIGP 44910, librigena, internal mould, x2.5; g, NIGP 44905, holotype cranidium (originally figured by Zhu & Lin 1978, Pl. 1, Fig. 8), internal mould, x3.



lines; narrow anterior border furrow. Librigena has wide border with terrace lines. Border widens posteriorly; extending into long genal spine. Pygidium with three axial rings plus terminus. Axis length about 0.55 that of pygidium. Pleural field with two deep pleural furrows and two shallower interpleural furrows which extend almost all the way across very wide pleural field. Pleural field has closely spaced terrace lines. Three pairs of pygidial spines; anterior pair long, extending posteriorly and slightly outwards to slightly inwards; second pair narrower and directed very slightly medially; third pair very short; medially from the third pair pygidial margin minutely denticulate; posterior margin deflected anteriorly at centre.

*Discussion:* The cephalon of *X. orientalis* is essentially the same as that of *X. yaxienensis*. However, the pygidia differ in that the anterior pair of spines of *X. orientalis* are much longer than and have a broader base than those of *X. yaxienensis*. The glabella anterior of *X. orientalis* is more sharply rounded than that of *X. hainanensis*. The anterior pair of spines on the pygidium of *X. hainanensis* is much longer than those of *X. orientalis*.

#### Genus GALAHETES Öpik, 1975

*Type Species:* *Galahetes fulcrosus* Öpik, 1975, p. 75, Pl. 16, Figs 1-4; Pl. 17; Pl. 18, Figs 1-3; Pl. 19, Figs 1-5; Pl. 20, Figs 1,2, text-figs 7c, 13.

*Diagnosis:* See Öpik 1975, p. 75.

#### *Galahetes hainanensis* Zhu & Lin, 1978

FIG. 6c,e,f,g.

*Galahetes hainanensis* Zhu & Lin, 1978, p. 441, Pl. 2, Fig. 4.

*Galahetes pyrus* Zhu & Lin, 1978, p. 442, Pl. 2, Figs 5-7.

*Material:* Ten cranidia.

*Holotype:* The cranidium (NIGP 44912) figured by Zhu & Lin 1978, Pl. 2, Fig. 4 and refigured here in Fig. 6c.

*Discussion:* The available specimens add nothing to the material figured in Zhu & Lin (1978). However, a re-examination of the material indicates that the

cranidia described by Zhu & Lin as *Galahetes pyrus* should be placed in the same species as that described as *G. hainanensis* and hence *G. pyrus* is a junior synonym of *G. hainanensis*. The apparent differences between *G. hainanensis* and *G. pyrus* are due to the effects of tectonic distortion. The holotype cranidium of *G. hainanensis* has been tectonically elongated while the cranidium figured as *G. pyrus* by Zhu & Lin has been tectonically shortened.

#### Order CORYNEXOCHIDA Kobayashi, 1935

##### Family DORYPYGIDAE Kobayashi, 1935

##### Genus KOOTENIA Walcott, 1889

*Type Species:* *Bathyrisceus (Kootenia) dawsoni* Walcott, 1889, p. 446.

*Diagnosis:* See Palmer 1968, p. 47; 1972, p. 18.

#### *Kootenia* sp.

FIG. 2g-i, 4f.

*Kootenia* sp. Zhu & Lin, 1978 p. 442, Pl. 2, Figs 8,9.

*Material:* Two incomplete cranidia and six incomplete pygidia.

*Remarks:* The available material includes two pygidia which are better preserved than that figured in Zhu & Lin (1978, Pl. 2, Fig. 9). The pygidial axis comprises five axial rings and a terminus. The axis extends to the wide posterior border furrow. Narrow border. There appear to be at least five pairs of small border spines. There are four pairs of pleural furrows.

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Fig. 6. a,b,h *Xystridura orientalis* Zhu & Lin 1978. a, NUESD 242, pygidium, x3; b, NUESD 241, pygidium, internal mould, x3; h, NUESD 250, librigena, rubber cast of external mould, x2.  
c,e,f,g. *Galahetes hainanensis* Zhu & Lin, 1978. c, NIGP 44912, holotype cranidium of external mould, (originally figured in Zhu and Lin 1978, Pl. 2, Fig. 4), x3; e, NIGP 44914, cranidium (originally figured in Zhu & Lin 1978, Pl. 2, Fig. 6 as *Galahetes pyrus*), x5; f, NUESD 215, cranidium, internal mould, x5; g, NIGP 44915, cranidium, rubber cast of external mould (originally figured in Zhu & Lin 1978, Pl. 2, Fig. 7 as *Galahetes pyrus*), x3.  
d, *Pagetia luoyacunensis* sp. nov., NUESD 208, pygidium, internal mould, x20.



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